

A&A 546, A92 (2012)
 DOI: [10.1051/0004-6361/201118725](https://doi.org/10.1051/0004-6361/201118725)
 © ESO 2012

The discovery of a shell-like event in the O-type star HD 120678^{★,★★,★★★} (Research Note)

R. Gamen^{1,★★★★}, J. I. Arias^{2,†}, R. H. Barbá^{2,3,†}, N. I. Morrell^{4,†}, N. R. Walborn⁵, A. Sota⁶,
 J. Maíz Apellániz^{6,‡}, and E. J. Alfaro⁶

¹ Instituto de Astrofísica de La Plata (CONICET) and Facultad de Ciencias Astronómicas y Geofísicas,
 Universidad Nacional
 de La Plata, Paseo del Bosque s/n, B1900FWA, La Plata, Argentina
 e-mail: rgamen@fcaglp.unlp.edu.ar

² Departamento de Física, Universidad de La Serena, Cisternas 1200 Norte, La Serena, Chile

³ Instituto de Ciencias Astronómicas, de la Tierra y del Espacio (ICATE-CONICET), Avda España 1512 Sur, J5402DSP, San Juan,
 Argentina

⁴ Las Campanas Observatory, Carnegie Observatories, Casilla 601, La Serena, Chile

⁵ Space Telescope Science Institute[‡], 3700 San Martin Drive, Baltimore, MD 21218, USA

⁶ Instituto de Astrofísica de Andalucía-CSIC, Glorieta de la Astronomía s/n, 18008, Granada, Spain

Received 22 December 2011 / Accepted 4 September 2012

ABSTRACT

Aims. We report the detection of a shell-like event in the Oe-type star HD 120678.

Methods. HD 120678 has been intensively observed as part of a high-resolution spectroscopic monitoring program of southern Galactic O stars and Wolf-Rayet stars of the nitrogen sequence.

Results. An optical spectrogram of HD 120678 obtained in June 2008 shows strong H and He I absorption lines instead of the double-peaked emission profiles observed both previously and subsequently, as well as a variety of previously undetected absorption features, mainly of O II, Si III and Fe III. Photometric data reveal that the development of the absorption spectrum coincided with a remarkable dip in the V-band lightcurve. The “shell phase” of HD 120678 did not persist for very long: the V magnitude recovered its previous average value in fewer than 120 days, whereas H and He emission lines became detectable one year later. Similar spectral variations have been observed in a few Be stars, and they are usually interpreted as changes in the circumstellar disk.

Key words. binaries: spectroscopic – stars: early-type – stars: emission-line, Be – stars: individual: HD 120678

1. Introduction

An intensive, high-resolution spectroscopic monitoring program of southern Galactic O and Wolf-Rayet stars of the nitrogen sequence (WN), designated the OWN Survey, is being carried out (Barbá et al. 2010). This observational campaign includes nearly all stars listed in the Galactic O-Star Catalogue (GOSC; Maíz Apellániz et al. 2004), as well as the WN stars cataloged in van der Hucht (2001, 2006), that are accessible from the southern hemisphere and bright enough to be observed at high resolution with 2-m class telescopes. The main goal of this long-term

program is the detection of radial-velocity and/or line-profile variations in the observed sample. Our OWN survey is coordinated with the GOS Spectroscopic Survey (GOSSS), which aims at observing all the stars in the GOSC, at intermediate resolution (Sota et al. 2011; Maíz Apellániz et al. 2011).

One of the targets of the OWN Survey is HD 120678 (CPD -62 3703), a bright ($V = 7.9$ mag) Galactic field star classified as O8 III:nep (Garrison et al. 1977). Oe stars represent the extension of the Be phenomenon to the O-type range. The spectra of these stars are fundamentally characterized by emission in the Balmer series lines. Emission lines of He I and Fe II, often with double-peaked morphology, are also detectable. Simultaneously, He II and other high-ionization lines, such as N III and Si IV, are observed in absorption. Since the Be phenomenon tends to become very rare for spectral types earlier than O9.5 (Negueruela et al. 2004), the few known Oe stars deserve detailed investigation, as they could provide important constraints on the physical mechanism generating the emission lines of these stars.

We recall here some milestones in the knowledge about HD 120678: Serkowski (1968) reported that this star is intrinsically polarized; Strohmeier (1972) found light variability; Whittet & van Breda (1978) detected a large infrared excess; and Meyer & Savage (1981) found peculiar UV extinction parameters. Finally, using IUE data, Massa et al. (1983) found that its

* Based on observations collected at the Complejo Astronómico El Leoncito (CASLEO), the Las Campanas Observatory, and the European Organisation for Astronomical Research in the Southern Hemisphere (proposals: 079.D-0564, 086.D-0997, and 087.D-0946).

** Table 2 and Fig. 4 are available in electronic form at <http://www.aanda.org>

*** Reduced spectra is available at the CDS via anonymous ftp to [cdsarc.u-strasbg.fr](ftp://cdsarc.u-strasbg.fr) (130.79.128.5) or via <http://cdsarc.u-strasbg.fr/viz-bin/qcat?J/A+A/546/A92>

**** Visiting Astronomer, Las Campanas Observatory, Chile and CASLEO, Argentina.

† Visiting Astronomer, Las Campanas and La Silla Observatories, Chile.

‡ Operated by AURA, Inc., under NASA contract NAS5-2655.

Table 1. Details of the spectroscopic data used in this work.

Date	n	Instr. Configuration	Observat.	R	Sp. Range [Å]
May-06	1	Echelle-REOSC, 2.15-m	CASLEO	15 000	3600–6100
May-06	1	Echelle, 2.5-m	LCO	40 000	3450–9850
Jul-06	1	Echelle, 2.5-m	LCO	40 000	3450–9850
Aug-06	1	MIKE, 6.5-m	LCO	33 000	3330–9400
Apr-07	2	Echelle-REOSC, 2.15-m	CASLEO	15 000	3600–6100
May-07	1	FEROS, 2.2-m	La Silla	46 000	3570–9210
May-07	2	Echelle-REOSC, 2.15-m	CASLEO	15 000	3600–6100
Jun-07	1	Echelle, 2.5-m	LCO	40 000	3450–9850
May-08	1	B&C, 2.5-m	LCO	2500	3910–5510
Jun-08	1	Echelle-REOSC, 2.15-m	CASLEO	15 000	3600–6100
Jul-09	1	B&C, 2.5-m	LCO	2500	3910–5510
Jan-10	1	MIKE, 6.5-m	LCO	33 000	3350–9100
May-10	4	Echelle, 2.5-m	LCO	40 000	3450–9850
Feb-11	2	FEROS, 2.2-m	La Silla	46 000	3570–9210
Feb-11	2	Echelle-REOSC, 2.15-m	CASLEO	15 000	3600–6100
Mar-11	3	FEROS, 2.2-m	La Silla	46 000	3570–9210
Apr-11	1	Echelle, 2.5-m	LCO	40 000	3450–9850
May-11	1	Echelle, 2.5-m	LCO	40 000	3450–9850
May-11	1	FEROS, 2.2-m	La Silla	46 000	3570–9210
Jun-11	2	FEROS, 2.2-m	La Silla	46 000	3570–9210
Jul-11	1	MIKE, 6.5-m	LCO	33 000	3330–9400
Sep-11	1	MIKE, 6.5-m	LCO	33 000	3330–9400

UV spectrum is that of a normal late-O dwarf, although based on the previous work, it had been concluded that HD 120678 was an Oe-type star with normal extinction, its visual and IR colors being affected by circumstellar emission. More recently, [Pojmanski & Maciejewski \(2004\)](#) determined a periodicity of about 272 days for the observed light variations. In spite of its singular characteristics, no detailed study of HD 120678 can be found in the present bibliography.

In this work, we report the discovery of a shell-like event in the spectrum of HD 120678, discussing some of its possible interpretations.

2. Observations

We observed the spectrum of HD 120678 from the Complejo Astronómico El Leoncito¹ (CASLEO) in Argentina, as well as from the La Silla (ESO) and Las Campanas (LCO) Observatories in Chile, during several nights between May 2006 and September 2011. Most of the observations were obtained with the echelle spectrographs attached to the 2 m class telescopes of these observatories. Three additional spectrograms were taken with the MIKE spectrograph at the 6.5 m LCO/Magellan II (Clay) telescope. Two more spectrograms were obtained with the Boller & Chivens (B&C) spectrograph attached to the 2.5 m LCO/du Pont telescope in the context of the GOSSS project. Table 1 presents the details of the spectroscopic data used in this work. Flat-field and bias frames were also observed each night. Spectra were processed and extracted from the two-dimensional images using IRAF² routines.

¹ CASLEO is operated under agreement between CONICET, SECYT, and the National Universities of La Plata, Córdoba and San Juan, Argentina.

² IRAF is distributed by the National Optical Astronomy Observatories, which are operated by the Association of Universities for Research in Astronomy, Inc., under cooperative agreement with the National Science Foundation.

3. Results

3.1. Description of the spectroscopic event

The optical spectrum of HD 120678 is usually dominated by emission lines of H, He I and Fe II. Emission lines of the Balmer and the Paschen series are seen to very high levels, i.e., from H α to at least H20, and from Pa10 to Pa23, respectively. A rich emission spectrum of metallic lines, including ions such as Fe II, Mg I-II, Si II, Ca II, and O I is also evident. In general, the emission-line profiles are highly variable showing preferentially a double-peaked morphology. Variations in both the separation and the ratio of the violet-to-red emission peaks, i.e., the V/R ratio, are observed. The equivalent widths (EW) of some lines also seem to show slight variations. On the other hand, absorption lines of He II (λ 4200, λ 4542, λ 4686, and λ 5411), C III (λ 4070, λ 4650), O III (λ 5592), N III (λ 4511, 4515, λ 4535), and Si IV λ 4089, can be also identified. It is important to note that the traditional spectral-classification criteria for OB stars ([Walborn & Fitzpatrick 1990](#); [Sota et al. 2011](#)), cannot be applied here, since the He I lines which are included in the temperature-sensitive ratios are filled-in by emission. However, the He II lines suggest a spectral type of O9-B0 according to the strength of the He II λ 4542 line. In the following, we will refer to the phenomenology described above as the “Oe phase” of HD 120678.

The spectrum of HD 120678 observed at CASLEO in June 2008 presents completely different characteristics. Figure 1 presents the variations observed in the 4400–4700 Å spectral range. Most of the spectral lines previously observed in emission, such as the Balmer and He I lines, are now observed as strong absorptions, although traces of emission remain present in some of them. On the other hand, some other emission features, such as Mg II λ 4481 and Fe II, are no longer detectable. Furthermore, a number of new absorption features become visible. We identify these new absorptions as O II, N II, C II, Si III, and Fe III, which we consider as originating in a shell according to their low ionization and narrow widths. In fact, the measured FWHM for these features is ~ 3 Å compared to the $FWHM \sim 6$ Å of the He II photospheric absorption lines. We thus consider the spectrum of HD 120678 obtained in June 2008 as arising in a Oe shell-like phase.

Higher ionization lines such as He II and Si IV are clearly the least affected, although a slight enhancement could be present. The strength of the He II lines suggests a late-O type, similar to that observed before the event. On the other hand, if we consider only metallic and He I lines, taking into account that Si III is stronger than Si IV, a B0.7-B1.5 type can be determined. N II and N III lines are, however, too strong for these spectral types, while the C III λ 4650 absorption appears relatively weaker. These facts suggest an additional ON/BN classification ([Walborn 1976](#)).

In summary, we found that the optical spectrum of HD 120678 changed dramatically its previous Oe appearance displaying two different sets of absorption lines: the one consisting of broad lines of high ionization (similar to those observed before) presumably arising in the photosphere, and the other consisting of narrower lines of lower ionization compatible with an early B-type, apparently arising in a shell. We will refer to the latter as the “Oe shell-like phase” of HD 120678. The shell ionization is intermediate between those of the photosphere and the disk.

It is worth mentioning that in May 2008, one month before the dramatic change previously described, we obtained an intermediate-resolution spectrogram which already shows some features in absorption, for instance He, H δ , O II λ 4661, 4675,

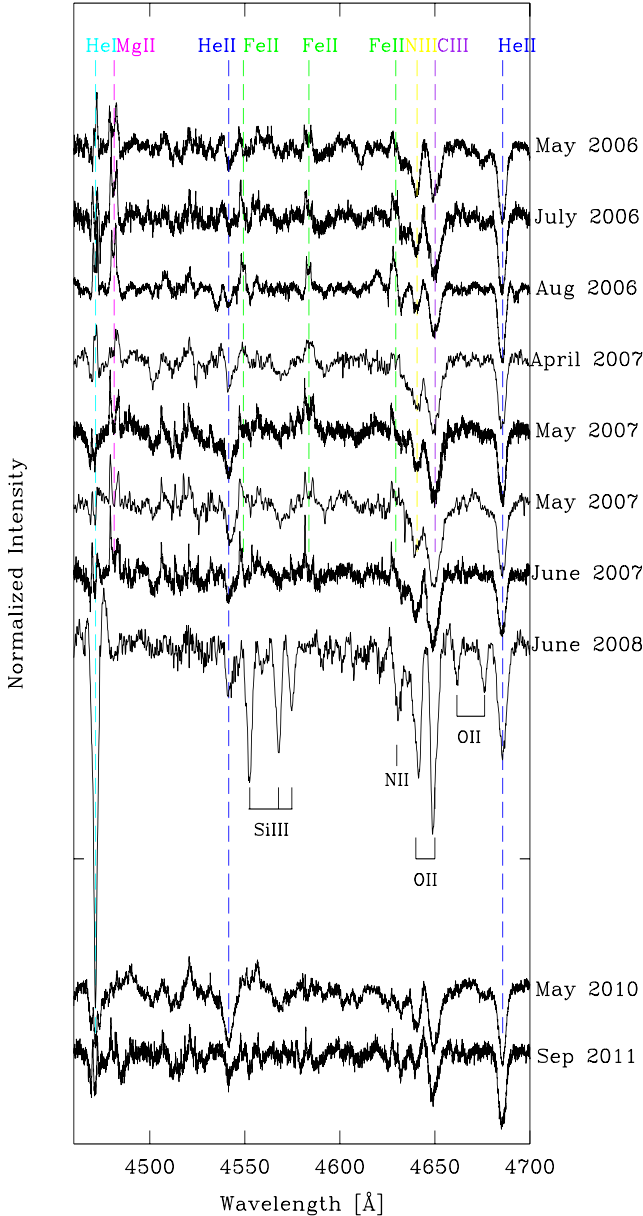


Fig. 1. Spectral variations of HD 120678 in the 4450–4700 Å wavelength range.

and Si III $\lambda\lambda 4553, 4568, 4575$. In fact, a progression from pure absorption in the violet part of the spectrum (e.g., He ϵ) to emission in the green part (e.g. H β) is particularly evident for the Balmer series lines (see Fig. 2). This spectrum constitutes a link between the Oe phase and the Oe shell-like phase spectra.

Subsequent data reveal that the Oe shell-like phase of HD 120678 did not persist for long. Another intermediate-resolution spectrum was taken in July 2009, one year after the almost pure absorption observed in June 2008. It also presents some absorption lines, again suggesting an intermediate stage. Nevertheless, the overall appearance of this spectrum is rather similar to that of the Oe phase spectra for wavelengths longer than H β . Finally, high-resolution spectrograms obtained between January 2010 and September 2011 suggest the complete return to the Oe phase. The morphology of the emission profiles is, however, rather different from that observed before the event, consisting of a well-defined, double-peaked structure with a V/R ratio clearly larger than unity. This V/R ratio inverts again

in the spectrum of September 2011. This last spectrum resembles the one obtained in August 2006, although the violet and red peaks appear comparatively more separated (see Fig. 2).

After this spectroscopic event was serendipitously observed, the question of whether or not it was really unprecedented arises. In pursuit of an answer, we searched the spectroscopic and photometric databases. Even though we did not find any spectrogram of HD 120678, we were surprised by the lightcurve generated from the All-Sky Automated Survey (ASAS; [Pojmanski 2002](#)), which will be described in the following section. Additionally, we found that this star is included in the Tycho-2 Catalogue (TYC 9008-3345-1; [Høg et al. 2000](#)) presenting photometry obtained between 1990 and 1993.

3.2. The ASAS lightcurve

The V-band lightcurve of HD 120678 generated by the ASAS survey is shown in Fig. 3. The first result is that the V magnitude of HD 120678 has been highly variable during the whole period covered by the ASAS data.

The lightcurve shows a relatively quiet trend with low-amplitude variations ($\Delta m_V < 0.2$ mag) until HJD $\approx 2\,453\,200$, when a rising phase begins. This ascending phase extends over ≈ 1400 days before the star undergoes a dramatic decline in light, in June 2008. With an approximate duration of 160 days, the observed decline showed an amplitude of $\Delta m_V \approx 0.85$ mag from maximum to minimum; it was followed by an also rapid but less steep rise³ ($\Delta m_V \approx 0.5$ mag), which lasted for about 120 days.

The epoch of the minimum in the ASAS lightcurve (HJD $\approx 2\,454\,645$) practically coincides with that of our high-resolution spectrogram showing the absorption features, i.e., the Oe shell-phase spectrum (HJD = 2 454 644.66). The first low-resolution spectrogram (showing an intermediate phase) was taken during the light decline, some 0.2 mag before the minimum, whereas the second one was obtained during the post-event period, when the lightcurve seemed to stabilize.

As mentioned before, the lightcurve in Fig. 3 reveals that HD 120678 experienced a slow, progressive increase in magnitude since HJD $\approx 2\,453\,400$. On the other hand, during the entire covered period prior to the event, the lightcurve shows fluctuations with an average amplitude $\Delta m_V < 0.1$ mag (except for a somewhat larger one observed around HJD $\approx 2\,452\,800$). These variations must certainly be what led [Pojmanski & Maciejewski \(2004\)](#) to include HD 120678 in their Catalog of Variable Stars, where this star is classified into the “miscellaneous” category (which includes all stars other than contact configurations, detached and semi-detached systems, and pulsating objects). These authors also found a periodicity close to 272 days.

Finally, the ASAS lightcurve also shows a hint that there could have been a similar event around JD $\approx 2\,452\,000$. In spite of their larger errors, the Tycho data were useful to demonstrate that, at least between 1990 and 1993, there was no other event comparable with that reported here.

3.3. The radial-velocity analysis

We now explore the hypothesis of binarity, based on the radial-velocity (RV) measurements derived from the high-resolution spectrograms of HD 120678. As described in Sect. 3.1, the high-ionization absorption lines in the spectrum of HD 120678 are apparently the least affected by the dramatic event of June 2008.

³ The rate of fading is about 0.005 V mag per day, whereas the rate of the ensuing brightening is 0.004 mag per day.

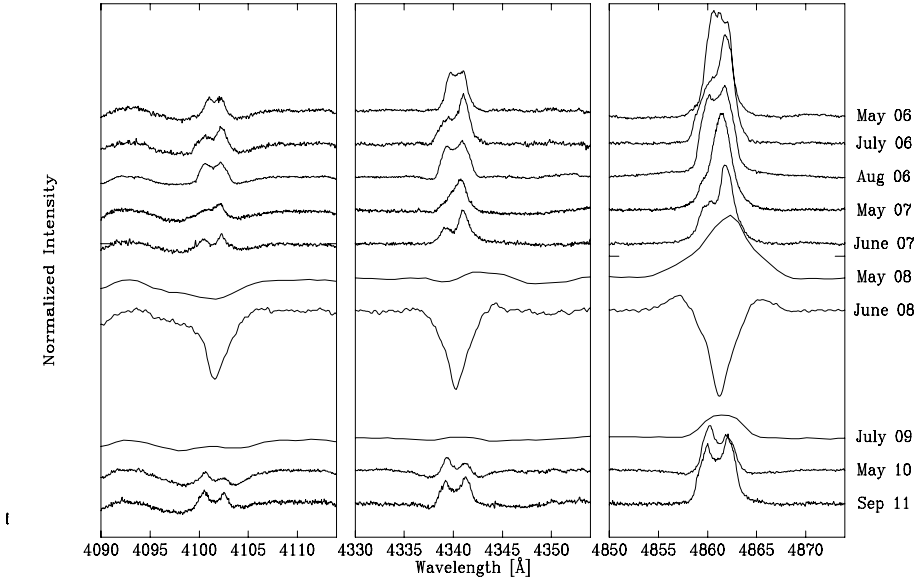


Fig. 2. Evolution of the H δ (left), H γ (center), and H β (right) profiles, observed in the spectra of HD 120678. Note the lower resolution of the May08 and Jul09 spectra.

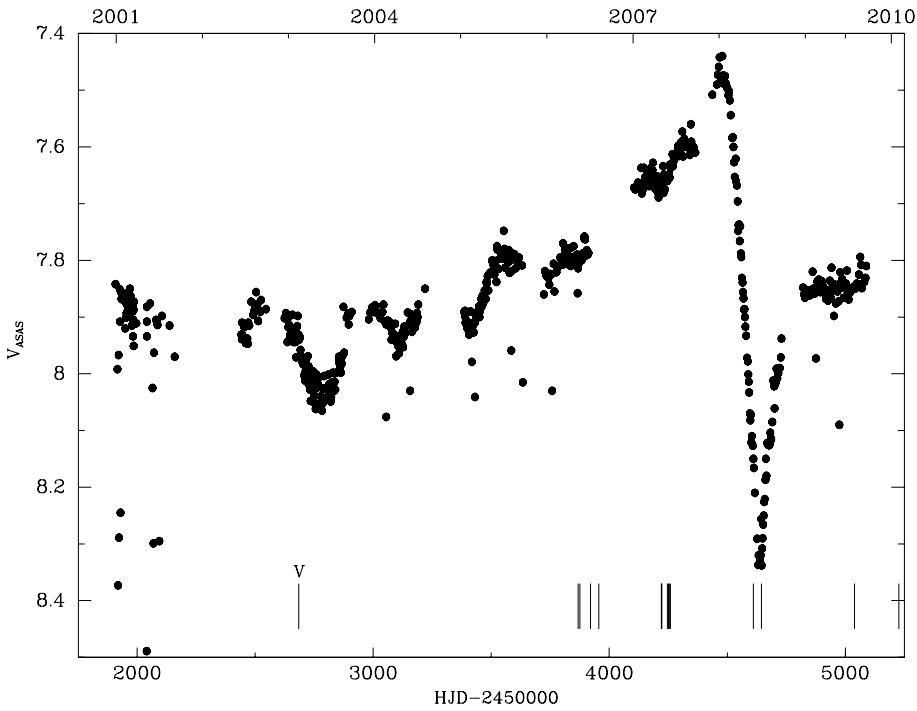


Fig. 3. ASAS lightcurve of HD 120678, covering 3200 days, from December 2000 to July 2009. The epochs of our spectroscopic observations are indicated by ticks at the bottom of the plot (the spectropolarimetric observation by Vink et al. 2009, is labeled with a “V”).

Consequently, we chose the He II $\lambda 4686$ and $\lambda 5411$ absorption lines, to determine their RVs (see Table 2). Obtaining satisfactory Gaussian fits was not straightforward, since most of the profiles are rather asymmetric and appreciably broadened by rotation, then we measured RVs by Fourier cross correlation via IRAF/FXCOR. In any event, the RVs are evidently variable, with a maximum amplitude of roughly 33 km s^{-1} and 17 km s^{-1} , for the He II $\lambda 4686$ and $\lambda 5411$, respectively (for comparison, the interstellar lines of Na I $\lambda\lambda 5890-95 \text{ \AA}$ show a maximum difference of 4 km s^{-1}). These RV variations, if periodic, would be indicative that HD 120678 is a binary or multiple system.

We searched the RV data for periodicities applying two different methods; namely, the improved analysis of expected mean square deviation (Marraco & Muzzio 1980) and the string-length method (Dworetzky 1983). The first method (using 5 bins) gave some probable periods, 280.1, 200.2, 63.0, and 77.3 days,

but only the most probable period $P = 280.1 \text{ d}$ is obtained simultaneously for both RV datasets. The second method did not give a robust result. Thus, the periodicity in the RVs of the He II absorption lines should be confirmed with further observations. In fact, the correlation between the RV measured in both He II lines is not obvious, perhaps indicating that they are formed in different regions.

We have also measured the violet (V) and red (R) components of the He I 5875 \AA emission line (originated in the disk, see Fig. 4), and searched them for periodicities. In this case, we obtained a most probable period of 70.9 days for the V component (using both methods) and 280.1 days for the R component. We discarded other values as they seem numerical artefacts. Although the persistence of the 280.1 d period (even in $\sim 4 \times 70.9$ days) very similar to the one obtained by Pojmanski & Maciejewski (2004) is noteworthy, we are reluctant to draw

definite conclusions about the binarity of HD 120678 until further observations are available.

4. Discussion

Balmer and other double-peaked emission lines observed in Oe/Be stars are usually interpreted as evidence of a circumstellar envelope concentrated toward the equatorial plane of the star, in the form of a disk. The origin of the gas in the disk is agreed to be material ejected from the stellar photosphere, although the precise mechanism through which these disks are formed remains elusive. Be stars show significant photometric, polarimetric, and spectroscopic variability with different time-scales and amplitudes. These stars are also known to occasionally switch from having a circumstellar disk (“Be phase”) to a state in which the disk seems to be completely dissipated (“normal B phase”). Observationally, these “phase transitions” are seen as a fundamental change of the Balmer (and possibly other) lines from strong emission to pure absorption. In contrast, stars in the “Be-shell phase” are characterized by narrow absorption cores in addition to the broad photospheric lines. The major variations observed in these stars are most probably due to physical changes in the circumstellar matter. The transitions among B, Be, and Be-shell phases are usually accompanied by pronounced light variations. Observations of these rare events are of special interest since they can provide important information about the physical mechanisms responsible for the formation, support, and loss of the disks around Be stars.

Remarkable examples of Oe/Be stars that have undergone shell-like events analogous to the one observed in HD 120678 are γ Cas (27 Cas), 28 Tau (Pleione), 59 Cyg (HD 200120), X Persei (HD 24534), and o And among others.

γ Cas (B0.5 IVe) has been extensively studied since its discovery as the first of its class in 1867. The long-term variations of this star, including changes in the Balmer emission lines, the visual apparent magnitude, and the V/R ratio, have been described by several authors (Doazan et al. 1983, and references therein). The occurrence of three phases – Be, Be-shell and B quasi-normal – has been reported. It has been observed that the star brightens when the emission in the Balmer lines increases, while it becomes fainter during the shell phases and the quasi-normal B phase. γ Cas is now known to be a 204-day binary with a low eccentricity (Miroshnichenko et al. 2002).

Pleione (B8e) showed cyclic changes between B, Be, and Be-shell phases during the last century (Tanaka et al. 2007). While entering each Be-shell phase, the star developed many shell absorption lines in its spectrum and showed, at the same time, a decrease in its brightness. The typical shell lines identified in the spectrum of Pleione (of Ti II, Cr II, Fe I and Fe II) are not those seen in the shell phase spectrum of HD 120678. The shell spectrum of HD 120678 is evidently hotter. Thus, B stars show an A/F-type shell spectrum, whereas O stars show a B-type shell spectrum. Pleione has recently been confirmed to be a binary with a period of 218 days (Nemravová et al. 2010).

The B1e star 59 Cyg has repeatedly shown very pronounced spectral variations. This star was confirmed to be an evolved Be+sdO binary system with a period of 28.2 days (Maintz et al. 2005). Barker (1982) provided a detailed description of its spectral behavior during an active phase characterized by spectacular emission-line variations and a 160 day shell episode. He proposed the existence of a relation between the stellar luminosity and the time scale for the dynamical processes in the circumstellar envelopes. The shell episode of HD 120678 is comparable in

duration to that observed in 59 Cyg and, consequently, one of the shortest reported at present.

X Persei is a Oe/X-ray binary system, which also underwent several phase changes in the recent decades. Clark et al. (2001) identified one episode of complete disk loss, characterized by a significant 0.6 mag optical fading and the presence of purely photospheric H α and He I λ 6678 lines, as well as two episodes of pronounced optical fading which did not result in the complete dispersal of the circumstellar disk.

The B6e star o And has also experienced shell and disk-loss episodes, as discussed in (Clark et al. 2003). Their Figs. 1 and 2 show the variations observed in H α during each kind of event. A comparison with our Fig. 2 (right panel) reveals that the spectrum of HD 120678 observed in June 2008 is compatible with a shell-like event rather than a disk-loss. Moreover, none of our observations resembles the pure photospheric H α profile observed during the disk-loss event of o And. This star, as well as the other examples here mentioned, belongs to a multiple stellar system (quadruple; Hill et al. 1988) such as the radial velocity variations reported in Sect. 3.3 also suggest for HD 120678.

Vink et al. (2009) did not detect a disk around HD 120678, in spectropolarimetric data obtained on 2003 February 13. However, we find strong evidence for a variable disk in our spectroscopic observations. As marked in Fig. 3, the observations of Vink et al. occurred near a pronounced minimum in the lightcurve, which might be related to their null result. Clearly more extensive spectropolarimetric temporal coverage would be required for definitive conclusions and might provide further useful information about the variable phenomena in this star.

It is known that companions can influence the circumstellar disks of Be stars in several ways: affecting the global disk oscillations (Oktariani & Okazaki 2009), truncating the outer disk (Carciofi et al. 2009), and even extracting material from the central star in eccentric orbits (Miroshnichenko et al. 2001; Kervella et al. 2008). The latter authors found that the orbital period of the close companion of Achernar (HD 10144) appears similar to the observed pseudo-periodicity of the Be phenomenon, indicating that an interaction between the components at periastron could be triggering the Be episodes. However, the role of binarity in the Be phenomenon remains unclear. As mentioned before, the low-amplitude modulation shown by the ASAS lightcurve of HD 120678, especially between JD \approx 2 453 000 and JD \approx 2 454 000, can probably be accounted for as ellipsoidal variations. Regarding the somewhat larger fluctuation observed around JD \approx 2 452 800, one may speculate that it could also be partly caused by a similar event (although much less dramatic) to that in June 2008, as both show similar morphologies and they might be related to periastron passages in an eccentric binary system. This speculation of course assumes an active role of the binary companion in the possible dissipation and regeneration of the circumstellar disk. Clearly, this area deserves further study.

An interesting behavior of these shell-like events is that the transition from double-peaked emission to absorption occurs at different times in each line, i.e., the bluer the line, the earlier it develops an absorption profile; conversely, the transition from absorption to emission occurs first in the redder lines. In the case of HD 120678, this is nicely shown by the two “intermediate” spectra obtained one month before (May 2008) and one year after (July 2009) the development of the shell phase (see Fig. 2). These spectra present H δ as well as the higher Balmer lines in absorption, H γ more or less neutral, and H β in emission. Similar variations were observed in γ Cas and 59 Cyg (see e.g. Cowley & Marlborough 1968; Barker 1982, respectively).

It is a well-known fact that Be stars are fast rotators, with rotational velocities comparable to the critical velocities (Hunter et al. 2008; Martayan et al. 2006), and it is also known that fast rotation plays a fundamental role in the evolution of massive stars (Maeder & Meynet 2000). Both stellar absorption lines and circumstellar emission features in HD 120678 are rotationally broadened. In order to estimate the $v \sin i$, we compared the observed He II absorption profiles with theoretical ones from TLUSTY (Lanz & Hubeny 2003) supposing a temperature range of 30 000–32 500 and a gravity range $\log g = 4.5$ –4.0. A value of $170 \pm 20 \text{ km s}^{-1}$ was obtained as the best estimate for the projected rotational velocity of HD 120678. Although it is still not clear why Be stars rotate so rapidly, one of the proposed scenarios involves close binary evolution. The relationship between rotational velocity and surface enrichments of processed material in massive stars is also a subject of current interest. Also, mass transfer in close binaries can produce rotational acceleration and changes in abundances on the stellar surfaces (Langer et al. 2008). Our spectra show enhanced N lines. Since HD 120678 is a fast rotator, rotational mixing might have played a role to increase the content of CNO-processed material on the surface. There is consensus to the effect that minimum values of $v/v_{\text{crit}} \leq 0.7$ have to be reached during the main sequence for the Oe/Be star phenomenon to occur. Depending on when this limit is reached, one expects more or less surface enrichments (Ekström et al. 2008). Thus, a precise knowledge of the abundance of the CNO elements could help to constrain the evolutionary stage of this star.

5. Summary

We report a shell-like event in the Oe star HD 120678, evidenced by striking spectral and photometric changes. Prior to June 2008, the spectrum of HD 120678 was characterized by the presence of emission lines, primarily H I, He I and low-excitation metals such as Fe II. By May–June 2008, dramatic changes in the emission-line profiles, from pure emission to absorption, were observed. At the same time, a number of previously undetected, considerably narrower absorption features (due to O II, N II, S III, etc.) became visible. We interpret these lower ionization lines as probably originating in a shell. Photometric data reveal that the absorption spectrum occurs in coincidence with a marked light minimum, reached after a very rapid decline which followed a secular brightening of the visual magnitude. The star did not persist for a long time in this state. The V magnitude started to brighten immediately, recovering its average value prior to the event in less than 120 days. Emission in the Balmer series was again detectable in a spectrogram obtained in July 2009. The analysis of the radial velocities measured in the high-resolution spectrograms of HD 120678 indicates variability whose origin is uncertain.

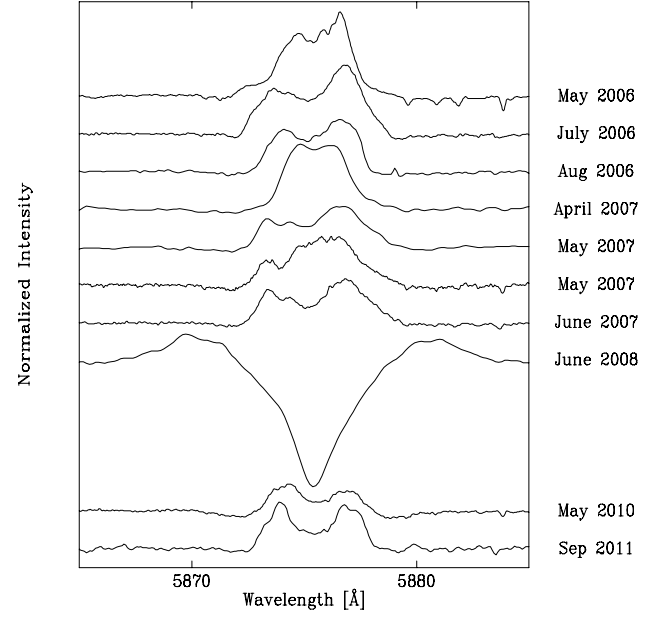
Acknowledgements. Support for this work was provided by the Spanish Government Ministerio de Ciencia e Innovación through grant AYA2010-17631, and FEDER funds; and the Junta de Andalucía grant P08-TIC-4075. This research has made extensive use of the SIMBAD database, operated at CDS, Strasbourg, France.

References

- Barbá, R. H., Gamen, R., Arias, J. I., et al. 2010, in *Rev. Mex. Astron. Astrofis. Conf. Ser.*, 38, 30
- Barker, P. K. 1982, *ApJS*, 49, 89
- Carciofi, A. C., Okazaki, A. T., Le Bouquin, J., et al. 2009, *A&A*, 504, 915
- Clark, J. S., Tarasov, A. E., Okazaki, A. T., Roche, P., & Lyuty, V. M. 2001, *A&A*, 380, 615
- Clark, J. S., Tarasov, A. E., & Panko, E. A. 2003, *A&A*, 403, 239
- Cowley, A. P., & Marlborough, J. M. 1968, *PASP*, 80, 42
- Doazan, V., Franco, M., Sedmak, G., Stalio, R., & Rusconi, L. 1983, *A&A*, 128, 171
- Dworetzky, M. M. 1983, *MNRAS*, 203, 917
- Ekström, S., Meynet, G., Maeder, A., & Barblan, F. 2008, *A&A*, 478, 467
- Garrison, R. F., Hiltner, W. A., & Schild, R. E. 1977, *ApJS*, 35, 111
- Hill, G. M., Walker, G. A. H., Dinshaw, N., Yang, S., & Harmanec, P. 1988, *PASP*, 100, 243
- Høg, E., Fabricius, C., Makarov, V. V., et al. 2000, *A&A*, 355, L27
- Hunter, I., Lennon, D. J., Dufton, P. L., et al. 2008, *A&A*, 479, 541
- Kervella, P., Domiciano de Souza, A., & Bendjoya, P. 2008, *A&A*, 484, L13
- Langer, N., Cantiello, M., Yoon, S.-C., et al. 2008, in *IAU Symp.* 250, eds. F. Bresolin, P. A. Crowther, & J. Puls, 167
- Lanz, T., & Hubeny, I. 2003, *ApJS*, 146, 417
- Maeder, A., & Meynet, G. 2000, *A&A*, 361, 159
- Maintz, M., Rivinius, T., Stahl, O., Stefl, S., & Appenzeller, I. 2005, *Publications of the Astronomical Institute of the Czechoslovak Academy of Sciences*, 93, 21
- Maíz Apellániz, J., Walborn, N. R., Galué, H. Á., & Wei, L. H. 2004, *ApJS*, 151, 103
- Maíz Apellániz, J., Sota, A., Walborn, N. R., et al. 2011, in *Highlights of Spanish Astrophysics VI*, eds. M. R. Zapatero Osorio, J. Gorgas, J. Maíz Apellániz, J. R. Pardo, & A. Gil de Paz, 467
- Marraco, H. G., & Muzzio, J. C. 1980, *PASP*, 92, 700
- Martayan, C., Frémat, Y., Hubert, A., et al. 2006, *A&A*, 452, 273
- Massa, D., Savage, B. D., & Fitzpatrick, E. L. 1983, *ApJ*, 266, 662
- Meyer, D. M., & Savage, B. D. 1981, *ApJ*, 248, 545
- Miroshnichenko, A. S., Fabregat, J., Bjorkman, K. S., et al. 2001, *A&A*, 377, 485
- Miroshnichenko, A. S., Bjorkman, K. S., & Krugov, V. D. 2002, *PASP*, 114, 1226
- Negueruela, I., Steele, I. A., & Bernabeu, G. 2004, *Astron. Nachr.*, 325, 749
- Nemravová, J., Harmanec, P., Kubát, J., et al. 2010, *A&A*, 516, A80
- Oktariani, F., & Okazaki, A. T. 2009, *PASJ*, 61, 57
- Pojmanski, G. 2002, *Acta Astron.*, 52, 397
- Pojmanski, G., & Maciejewski, G. 2004, *Acta Astron.*, 54, 153
- Serkowski, K. 1968, *ApJ*, 154, 115
- Sota, A., Maíz Apellániz, J., Walborn, N. R., et al. 2011, *ApJS*, 193, 24
- Strohmeier, W. 1972, *Information Bulletin on Variable Stars*, 610, 1
- Tanaka, K., Sadakane, K., Narusawa, S., et al. 2007, *PASJ*, 59, L35
- van der Hucht, K. A. 2001, *New Astron. Rev.*, 45, 135
- van der Hucht, K. A. 2006, *A&A*, 458, 453
- Vink, J. S., Davies, B., Harries, T. J., Oudmaijer, R. D., & Walborn, N. R. 2009, *A&A*, 505, 743
- Walborn, N. R. 1976, *ApJ*, 205, 419
- Walborn, N. R., & Fitzpatrick, E. L. 1990, *PASP*, 102, 379
- Whittet, D. C. B., & van Breda, I. G. 1978, *A&A*, 66, 57

Table 2. RVs of some lines measured in the spectra of HD 120678.

HJD-2 450 000	He II 5411	He II 4686	He I 5875	
	abs.	abs.	em. V	em. R
3867.754	8.3	-11.8	-46.4	53.2
3875.692	2.8	-12.7	-43.9	50.5
3920.601	1.4	-18.8	-63.2	55.9
3955.477	-11.1	-7.4	-54.6	55.8
4220.764	0.8	-10.0	-41.2	27.4
4222.741	-3.0	-19.8	-40.3	27.5
4246.682	-18.4	-16.7	-44.9	38.3
4251.664	-6.9	-16.2	-75.5	36.9
4253.651	9.4	-10.8	-80.2	38.5
4258.701	5.7	-19.6	-77.7	58.3
4644.661		-7.6		
5226.833	4.3	-9.9	-54.2	65.2
5337.748	14.1	-9.7	-62.4	64.1
5339.779	11.2	-5.3	-62.4	64.6
5340.642	8.4	-7.1	-60.9	64.9
5341.664	6.8	-8.4	-58.0	65.1
5604.885	10.6	-9.6	-73.1	67.2
5606.863	4.9	-11.1	-73.1	66.5
5615.822	12.8	-15.7	-67.0	64.3
5618.750	-12.0	-22.6	-66.5	48.5
5641.745	-0.7	-12.7	-44.5	38.1
5642.892	4.9	-12.4	-43.8	33.4
5643.902	6.8	-13.3	-42.5	32.0
5671.782	8.7	-17.4	-76.2	54.2
5696.797	2.7	-14.4	-59.8	50.8
5697.741	7.3	-17.4	-60.0	52.3
5730.508	6.2	-8.5	-62.9	53.8
5730.524	2.4	-9.6	-60.9	54.3
5760.450	5.3	-7.1	-65.0	45.6
5807.475	13.1	-14.2	-73.1	56.0

**Fig. 4.** Spectral variations of HD 120678 in the He I 5875 Å wavelength range.